Cloud Condensation Nuclei

Cloud Processing

Activation
Evaporation

Diameter (µm)

Hoppel Minimum

- Particle evolution in remote marine conditions
- Cloud processing – growth of particles due to coalescence and solute condensation in cloud

Seinfeld and Pandis, Fig. 15.23 (Hoppel et al., 1990)

Number Distributions vs. Population Distributions

Human Population Age Distribution (Manhattan)

Aerosol Particle Size Distribution (Manhattan)

Population

Age

0 20 40 60

0.01 0.1 1 10

Dp (µm)

Particle Size Distributions

- Number concentration
  - Total number N
  - Differential number n
- Mean size
  - Geometric
  - Arithmetic
  - Number-based
  - Mass-based
- Size variability
  - Standard deviation $\sigma$
  - Geometric standard deviation $\sigma_g$

Particle Characteristics

- Concentration and size
- Chemical composition
- Light scattering

Size Characterization of Particles

- Clusters of molecules
- Starting at 100 molecules/cluster
- Growth by condensation of molecules is nearly continuous
- Multiple ways to graph same distribution
Particle Sizes

- range of particle sizes is approximately from 1 nm to 1 mm in diameter
- range of approximately 6 orders of magnitude
- concentrations at each of these sizes also vary

Size Distribution Modes

- modes of aerosol are distinguished by
  - size
  - sources
  - behavior

Log-Normal Number Distributions

- Cumulative
- Differential

Microphysics

- Aerosol includes both particles and vapor
- Number, area, volume, mass vary nonlinearly
- Deposition velocity depends on size (nano, micro, milli)
- Scavenging, coalescence, activation and condensation change the size distribution

Global Aerosol Distribution

- Regional variations in aerosol mass and composition

Capaldo et al., *Nature*, 1999

Toronto (1997-99)
Egbert (1994-99)
Abbotsford (1994-95)
Quaker City OH (1999)
Arendstville PA (1999)
Atlanta (1999)
Yorkville (1999)
Mexico City - Pedregal (1997)
Los Angeles (1995-96)
Fresno (1988-89)
Kern Wildlife Refuge (1988-89)
Washington DC (1996-99)
Colorado Plateau (1996-99)
Mexico City - Netzahualcoyotl (1997)
Esther (1995-99)
St. Andrews (1994-97)

Sulfate
Nitrate
Ammonium
Black carbon
Organic carbon
Soil
Other

12.3 ug m^{-3}
8.9 ug m^{-3}
7.8 ug m^{-3}
12.4 ug m^{-3}
10.4 ug m^{-3}
19.2 ug m^{-3}
14.7 ug m^{-3}
55.4 ug m^{-3}
30.3 ug m^{-3}
23.3 ug m^{-3}
39.2 ug m^{-3}
24.6 ug m^{-3}
14.5 ug m^{-3}
3.0 ug m^{-3}
24.6 ug m^{-3}
5.3 ug m^{-3}
4.6 ug m^{-3}
ROAST Reviews

- Review comments due to editor: Nov. 6
  - Reviews are completed by individuals not groups.
  - Reviewer’s name should not appear in review.
  - Reviewer’s name should be in filename.
- *GroupAp1ReviewLASTNAME.pdf*

Example Ch. 5 Prob. 7

Curry and Webster, p. 158, Problem 7a-c

1. An analytic expression of the following form has been used to describe drop size spectra:

\[ n(r) = A r^3 \exp(-Br) \]

where A and B are parameters. For a drop size spectrum expressed by this relationship, determine the following:

a) the total drop concentration per volume of air:

\[ N = \int_0^\infty n(r) \, dr \]

b) the mean drop radius:

\[ r = \frac{1}{N} \int_0^\infty r \, n(r) \, dr \]

Example Ch. 5 Prob. 7

\[ r = 3 \mathcal{N} \int_0^\infty r \, e^{-2B(r-1)} \, dr \]

Integral Tables (521), CRC 1986 p. 330

\[ \int e^{-2B(r-1)} \, dr = -\frac{1}{2} e^{-2B(r-1)} \]

Homework Ch. 5 Prob. 3

\[ r^m = \sqrt[m]{\frac{3B}{a}} \]

\[ S_n = 1 + \frac{4a^2}{27b} \]

Example Ch. 5 Prob. 7

\[ a = 2\rho_0(r_0R_nT) \]

\[ b = 3\rho M \frac{\rho_m}{2M_m \rho} \]

Example Ch. 5 Prob. 7

\[ a = 2\rho_0(r_0R_nT) \]

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Example Ch. 5 Prob. 7

\[ N = \frac{2A}{B} \]
Example Ch. 5 Prob. 7

4) the liquid water mixing ratio, \( w_l \):

\[ n(r) = A r^2 \exp(-Br) \]

\[ w_l = \frac{\rho_l}{\rho} \int_0^r n(r) \, dr \]

\[ \int s^m e^{-\alpha r} \, ds = \sum \left[ \frac{-1}{m} \right] \frac{1}{(m - r) \alpha} \]

\[ w_l = \frac{4 \pi A \rho_a}{3 \rho} \int_0^r s^m e^{-\alpha r} \, dr \]

\[ \frac{4 \pi A \rho_a}{3 \rho} \left[ \frac{-120B}{B} + \frac{160 \pi A \rho_a}{B \rho_a} \right] \]

\[ \frac{4 \pi A \rho_a}{3 \rho} \left[ \frac{1}{B} + \frac{160 \pi A \rho_a}{B \rho_a} \right] \]

\[ \frac{4 \pi A \rho_a}{3 \rho} \left[ \frac{1}{B} + \frac{160 \pi A \rho_a}{B \rho_a} \right] \]

Integral Tables (521)

CRC 1986 p. 330

Cloud in a Jar Demonstration

Adiabatic Processes

Expansion Cloud Chamber

– A rubberized film is the top of a glass jar, which contains a small amount of water.
– Close the water举报 in the jar to introduce the air with water vapor.
– Bring a heated metal strip the jar and put the bulb on the jar.
– Remove and release the bulb rapidly to cause the glass jar to cool available. The speed of the water vapor is reduced.

http://groups.physics.umn.edu/demo/old_page/demo_gifs/4B70_20.GIF

Lecture Ch. 6a

Saturation of moist air

• Relationship between humidity and dewpoint
  – Clausius-Clapeyron equation

• Dewpoint
  – Temperature
  – Depression

• Isobaric cooling

Curry and Webster, Ch. 6

How does saturation occur?

– By increasing water vapor
  – Evaporation of water at surface
  – Evaporation of falling rain

– By cooling
  – Isobaric
  – Radiative cooling of rising air

– By mixing of two unsaturated air parcels

Curry and Webster, Ch. 6

Saturation of Moist Air

• Dew point temperature

The temperature at which saturation is reached in an isobaric cooling process is the dew-point temperature, which is illustrated in Figure 6.1a. The dew point temperature, denoted by \( T_d \), can be defined by

\[ e = e_d(T_d) \]  \hspace{1cm} (6.4a) \]

or equivalently by

\[ w_v = w_{v_d}(T_d) \]  \hspace{1cm} (6.4f) \]

Curry and Webster, Ch. 6